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## Compression Therapy: Effects of Posture and Application Techniques on Initial Pressures Delivered by Bandages of Different Physical Properties

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**Objective.** To define the pressures and gradients achieved by different bandages when applied by alternative bandaging techniques.

**Methods.** An experienced bandager applied six bandages to the same leg of a volunteer using three application techniques. Pressure measurements were taken at the ankle, gaiter, calf and upper calf in three postures.

**Results.** All bandages gave consistent pressures with all standard deviations falling below 7 mmHg. The percentage increase in pressure from resting leg to standing was inversely related to bandage elasticity. Pressures were similar at the upper calf among the bandages for each application technique in each posture (differences <10 mmHg). Small differences in pressure among the bandages (4–15 mmHg) occurred at the ankle for the resting leg with a reduction in pressure between 6 and 63% at the upper calf compared to the ankle. These differences in ankle pressure were more marked on sitting (differences 15–18 mmHg) and standing (differences 15–27 mmHg), which resulted in substantial differences in gradients.

**Conclusions.** Striking variations in pressures and gradients were observed between bandages of different physical properties applied using alternative application techniques. In order to achieve clinical benefits without tissue damage, it is essential that the therapist appreciates how a bandage will react with a specific application technique.

**Keywords:** Bandaging; Compression therapy; Application techniques; Pressure measurements; Venous disease.

### Introduction

Bandages with many different characteristics are now marketed for compression treatment. Their physical effects are not always well defined or understood by those who prescribe or apply them. Clinical trials on compression therapy have been published without any evaluation of the properties or performance of the materials employed. Bandages are applied using a number of different bandaging techniques. Inappropriate selection or application of a bandage could lead to lack of efficacy and to adverse effects including amputation.<sup>1</sup> We have undertaken a series of laboratory studies of compression bandaging, each study designed to answer specific questions. We have reported a comparative experiment evaluating three commercially available pressure monitoring devices.<sup>2</sup>

This was followed by a comparative evaluation of multi-layer bandaging systems on models.<sup>3</sup> The present study was conducted on a human volunteer and assessed the pressures achieved using different bandages applied by alternative bandaging techniques, and how the pressures change with changes in posture. We considered that measurements on a normal limb should be made prior to investigating patients with venous disease.

### Aims

The aim was to define the pressures and profiles, with different postures, achieved by bandages of different physical characteristics. More specifically:

1. Do similar bandages give similar pressures/gradients?
2. How does cohesion effect pressures/gradients?
3. Which bandages/application techniques provide the most consistent pressures?

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4. How does posture effect different bandages/application techniques?

## Materials and Methods

Six bandages were applied in random order to the same leg by the same expert bandager in a 'block' during a half-day session. Five blocks were completed for each of three bandaging techniques. The experimental design for one block and one application method is shown in Fig. 1. In accordance with standard practice, a layer of orthopaedic wool (Surepress) was applied in a spiral from toe to knee to protect the leg before applying the compression bandage (changed before each block).

Measurements were taken within 5–10 min of application with the Borgnis Medical Stocking Tester (MST), the sensor of which is designed to measure sub-bandage pressures at four fixed points on the leg. The ankle measurement point was placed 5 cm above the lateral malleolus. The gaiter point then fell 8 cm above, the calf point 11 cm above that and the upper calf 11 cm higher again. The subject did five 'marking time' steps after each bandage application before pressure measurements were taken. The postures were: (i) standing with weight equally distributed on both legs; (ii) sitting with feet on the floor and knees at right angles; and (iii) sitting with legs parallel with the floor and feet resting on a stool.

The left leg of the same 30-year-old female subject, of average build and 180 cm in height, was used in all experiments. The circumferential leg measurements

were: ankle 24.0 cm, gaiter 26.0 cm, calf 38.0 cm, and upper calf 40.5 cm. The shoe size was 8 and the length of the tibia was 42 cm.

Extensible bandages of two main types were used: elastic and non-elastic. Elastic (E) bandages contain elastomers, latex or elastane, which return to their original length after stretching. Non-elastic (NE) bandages are extensible because the fibres used in their construction are crimped and do not recover their original length. The bandages were either cohesive or non-cohesive. Cohesive bandages adhere to only themselves but not to skin or non-cohesive bandages.

The bandages are listed below. The percentage increase in length on full extension (as measured on a 20 cm sample of each bandage) is given in parentheses.

1. Actiban (Activa Healthcare). Non-cohesive, NE: 100% cotton (35%).
2. Comprilan (Beiersdorf). Non-cohesive, NE: 100% cotton (35%).
3. Actico (Activa Healthcare). Cohesive, E: 60% cotton, 39% polyamide, 1% elastane (40%).
4. Secure Forte (Johnson and Johnson). Cohesive, E: 98% cotton, 2% elastane (50%).
5. Coban (3M). Cohesive, E: Dacron, polyester and latex (55%).
6. Tensopress (Smith and Nephew). High compression non-cohesive, E: 67% cotton, 33% viscose yarn with a covered elastomeric yarn (70%).

Three established techniques were used: the simple spiral (Fig. 2),<sup>4</sup> the figure of eight<sup>5</sup> (Fig. 3)<sup>4</sup> and the Pütter method (Fig. 4).<sup>4</sup> All bandages were applied from the base of the toes to the tibial tuberosity by

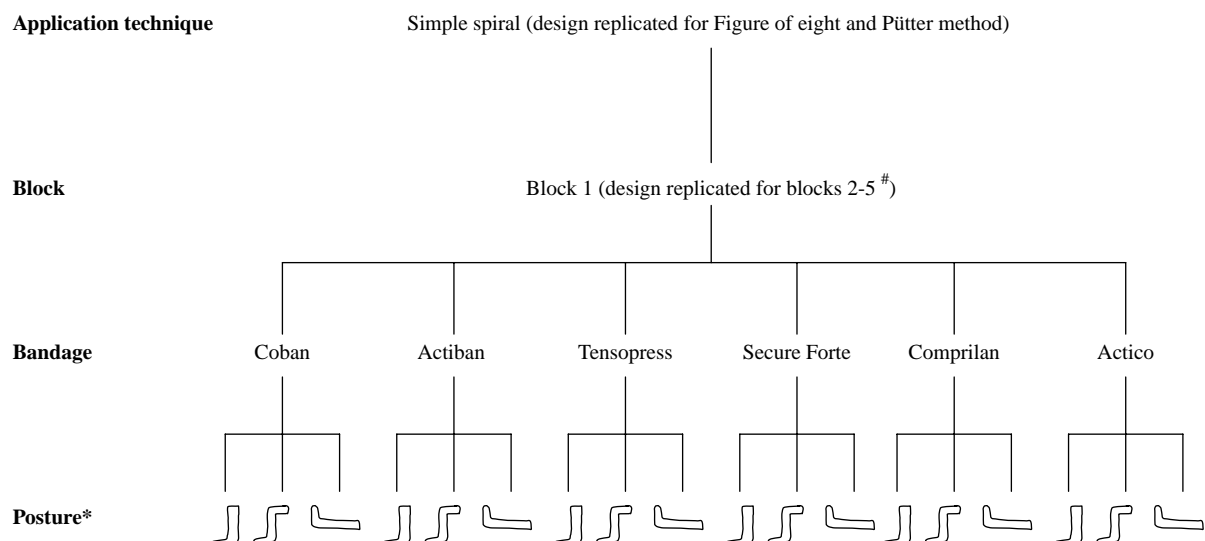


Fig. 1. Design of study illustrated for the first block of simple spiral.

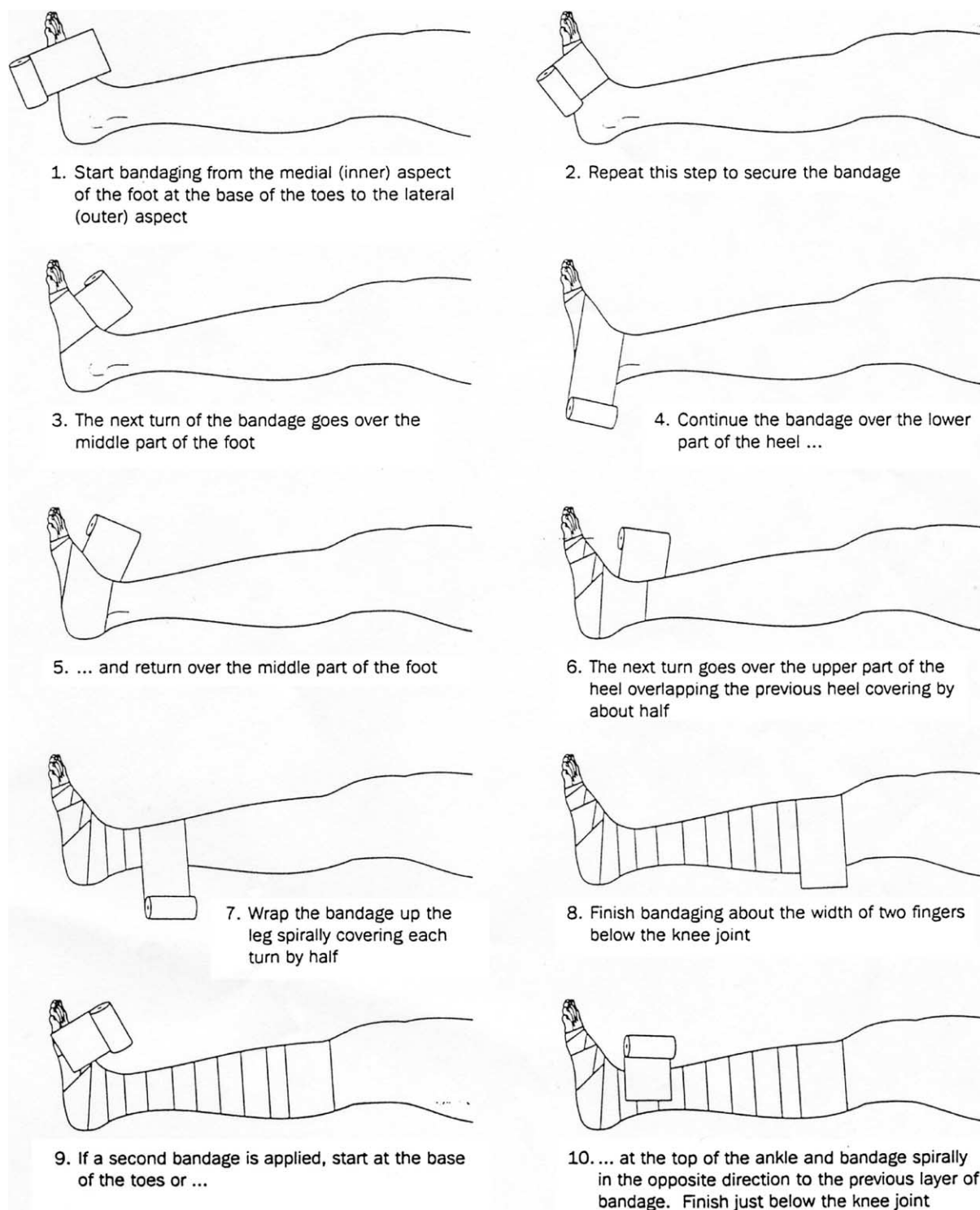


Fig. 2. Simple spiral bandaging technique illustrated.

a specialist nurse skilled and practised in all three techniques. A mirror positioned underneath the leg was used to ensure precise bandage application on the posterior aspect. The Pütter method was designed for use with only non-cohesive elastic bandages,<sup>4</sup>

however, for completeness of the experiment the method was used for the full range of bandages. The elastic bandages were applied at an estimated 50% of their full extension and the non-elastic bandages at full extension.

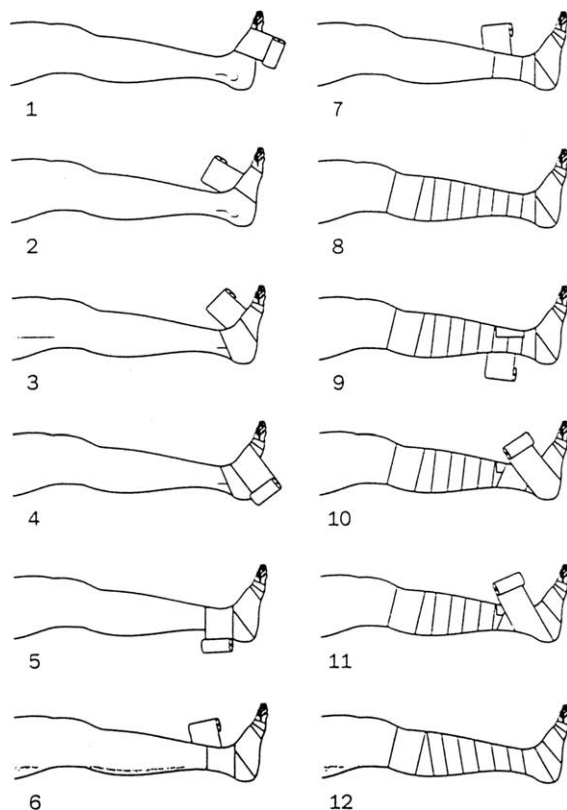


Fig. 3. Figure of eight bandaging technique illustrated.

#### Statistics

Analysis of variance (ANOVA) was used to assess the effect among bandage types, application techniques and posture, with blocks as a random effect.<sup>6</sup> In order to allow for the anticipated relationship between the different points, measuring points were entered into the model as a repeated measure. A Toeplitz covariance structure was used for the measuring points so the correlation between two adjacent measuring points was the same. Interactions were included in the models if  $p < 0.01$ . To illustrate the pressures obtained in the presence of higher order interactions, the mean pressures over the five blocks were examined graphically.

The standard deviation (SD) over the five blocks was calculated for each combination of factors. A pooled SD was then calculated for each application method and bandage combination, as well as for each bandage and each application method separately.

#### Results

In all 1080 observations were made, 180 for each bandage, 270 for each measuring point, 360 for each

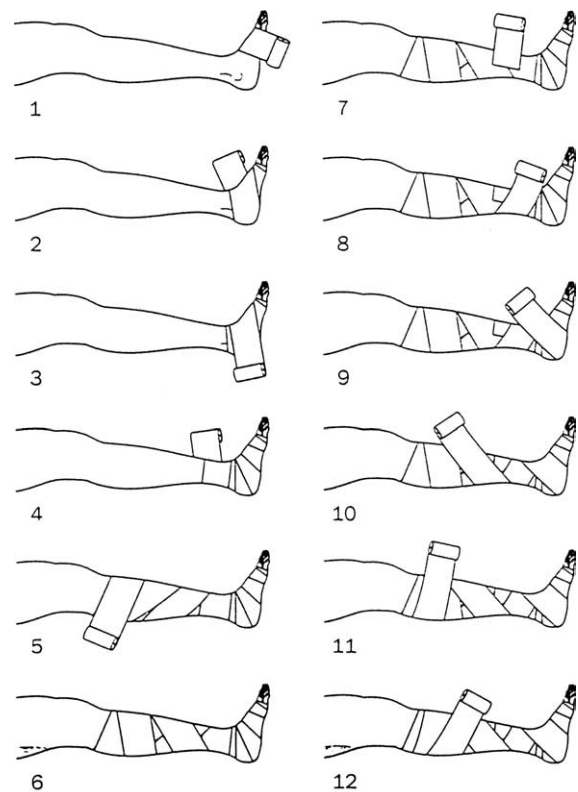


Fig. 4. Pütter bandaging technique illustrated.

application technique, 360 for each posture and 216 for each block.

#### Average pressure and gradient

The mean pressures are given in Table 1. The overall mean pressure was 30.0 mmHg ranging from a mean pressure of 37.8 mmHg at the ankle to 20.9 mmHg at the upper calf. The pressures were always higher at the ankle than the upper calf, but in 79 (29%) cases this was not a progressive gradient over all four measuring points.

The mean pressure at the ankle, gaiter, calf and upper calf positions are shown for each posture, application technique and bandage in Fig. 5 for non-cohesive bandages and Fig. 6 for cohesive bandages. Fig. 7 shows the differences in mean pressure and gradient between non-cohesive NE (stretch extensions 35%) and cohesive E bandages (stretch extensions 40–55%).

#### Non-cohesive bandages

##### Comparison of the two non-cohesive NE bandages (Actiban and Comprilan)

From Fig. 5, it can be seen that the pressures and gradients were similar between Actiban and

Table 1. Mean pressures for all bandages

Effect	Level	Mean (SE) pressures					
		Non-cohesive bandages			Cohesive, elastic bandages		
		Non-elastic		Elastic	Actico	Secure Forte	Coban
		Actiban	Comprilan	Tensopress			
Application technique	Simple spiral	32.6 (4.50)	32.7 (3.89)	29.0 (2.92)	30.0 (3.17)	31.3 (2.57)	28.5 (1.97)
	Figure of eight	23.5 (2.95)	26.8 (3.13)	28.3 (3.10)	25.1 (2.70)	29.3 (2.95)	20.7 (1.56)
	Pütter method	36.8 (3.94)	33.1 (3.84)	32.2 (1.37)	32.7 (2.90)	29.0 (2.02)	37.8 (2.55)
Posture	Resting leg	21.6 (1.74)	21.8 (1.19)	25.4 (1.79)	22.3 (1.54)	22.7 (1.09)	22.8 (1.77)
	Sitting	30.4 (2.88)	30.1 (2.44)	29.9 (2.37)	28.7 (2.23)	29.5 (1.41)	29.6 (2.59)
	Standing	40.9 (4.95)	40.7 (4.26)	34.3 (2.90)	36.9 (3.34)	37.4 (2.60)	34.6 (3.15)
Measuring point	Ankle	41.8 (5.54)	40.3 (4.85)	38.9 (2.42)	38.0 (3.65)	34.5 (3.14)	33.4 (3.95)
	Gaiter	35.1 (3.84)	36.0 (3.90)	33.0 (1.78)	33.0 (2.81)	32.9 (2.66)	31.5 (3.35)
	Mid-calf	27.9 (2.61)	27.2 (1.99)	26.4 (1.33)	26.1 (1.93)	29.9 (2.07)	27.8 (2.32)
	Upper calf	19.0 (2.92)	20.0 (1.83)	21.1 (2.20)	20.0 (1.99)	22.2 (1.90)	23.4 (2.89)

Comprilan. Using ANOVA, a significant interaction between bandage and application technique occurred when comparing Actiban and Comprilan. Therefore, each application technique was examined separately.

For the simple spiral, there was a significant interaction between bandage and measuring point ( $p=0.010$ ). The pressures for Actiban varied over a larger range (least square (LS) mean at ankle 45.2 mmHg compared to 17.6 mmHg at upper calf—a decrease of 61%) compared to Comprilan (43.0 mmHg at ankle compared to 22.1 mmHg at upper calf—a decrease of 49%). There was a significant difference in the mean pressures when they were applied in a figure of eight ( $p=0.003$ ) with the mean pressures higher for Comprilan (LS mean 26.8 mmHg) compared to Actiban (23.6 mmHg). When the bandages were applied using the Pütter method, the pressure for Actiban was significantly ( $p<0.001$ ) higher (LS mean 37.1 mmHg) than for Comprilan (32.8 mmHg).

#### Tensopress

The non-cohesive E bandage Tensopress follows a similar gradient pattern to the non-cohesive NE bandages, with the following three exceptions, noted from Fig. 5: (a) the simple spiral mean pressures are lower on standing for Tensopress at the ankle, gaiter and mid-calf (means 51.6, 37.6 and 29.4 mmHg, respectively) compared to the NE bandages (means 63.8, 50.4 and 40.1 mmHg, respectively); (b) the mean pressure is higher for the figure of eight with the resting leg at the ankle and gaiter for Tensopress (means 34.2 and 30.8 mmHg, respectively) compared to the NE bandages (means 24.5 and 23.3 mmHg, respectively); and (c) the mean pressures are lower for

the Pütter method on standing for Tensopress at the ankle and gaiter (means 42.0 and 37.2 mmHg, respectively) compared to the NE bandages (means 65.1 and 54.6 mmHg, respectively) producing a markedly smaller gradient (mean percentage change in pressure from ankle to upper calf  $-51$  and  $-25\%$ , respectively).

#### Cohesive bandages

##### Comparison of the three cohesive E bandages (Actico, Secure Forte and Coban)

Using ANOVA, a significant interaction between bandage and application technique occurred. Therefore, each application technique was examined separately (Fig. 6).

When applied in a simple spiral, there was a significant difference ( $p=0.046$ ) in mean pressure among the three cohesive bandages (LS means: 30.0 mmHg for Actico, 31.3 mmHg for Secure Forte and 28.5 mmHg for Coban). Additionally, there was a significant interaction between bandage and measuring point ( $p<0.001$ ) with a smaller percentage change from ankle to knee for Coban ( $-20\%$ ) compared to Secure Forte ( $-34\%$ ) and Actico ( $-49\%$ ). No significant interaction between bandage and posture was present ( $p=0.83$ ).

For the figure of eight, there was a significant difference ( $p<0.001$ ) in the mean pressures among the three bandages (LS means: 25.1 mmHg for Actico, 29.3 mmHg for Secure Forte and 20.7 mmHg for Coban) as well as a significant interaction between bandage and measuring point ( $p<0.001$ ) with a smaller percentage change from ankle to knee for Coban ( $-43\%$ ) compared to Secure Forte ( $-53\%$ ) and Actico ( $-55\%$ ).



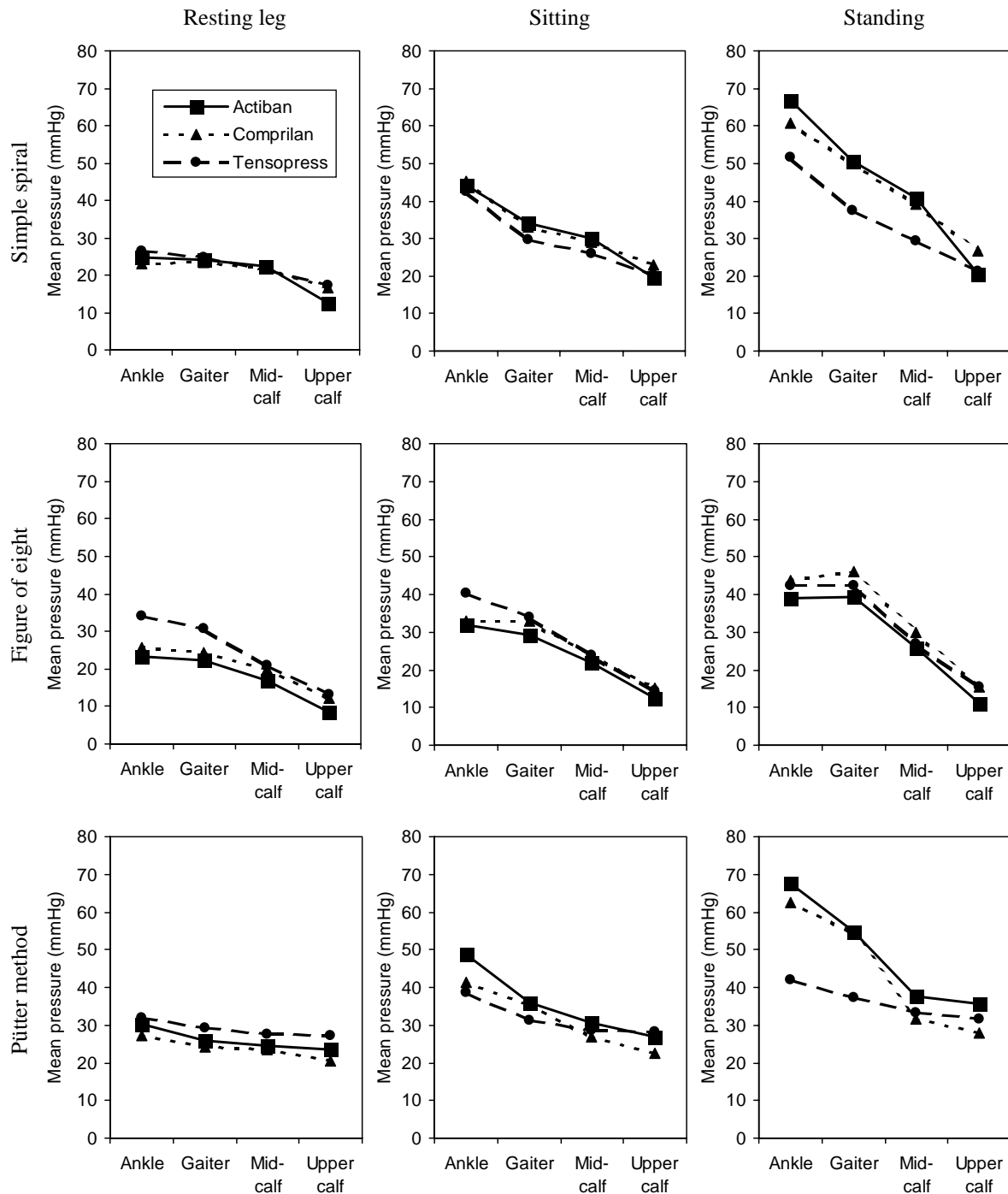


Fig. 5. Mean pressure over five blocks for each non-cohesive bandage for different application techniques and postures.

A similar pattern of differences occurred for the Pütter method as for the simple spiral, except the bandages with the highest pressures for simple spiral had the lowest pressures for the Pütter method and the percentage change from ankle to knee for Coban (−30%) fell between that for Actico (−40%) and Secure Forte (−19%).

#### *Effect of cohesion on pressures and gradients*

The mean pressure over the three cohesive E bandages and the two non-cohesive NE bandages were compared (Fig. 7). Tensopress was excluded from the comparison because its stretch extension was considerably more than the other non-cohesive bandages.

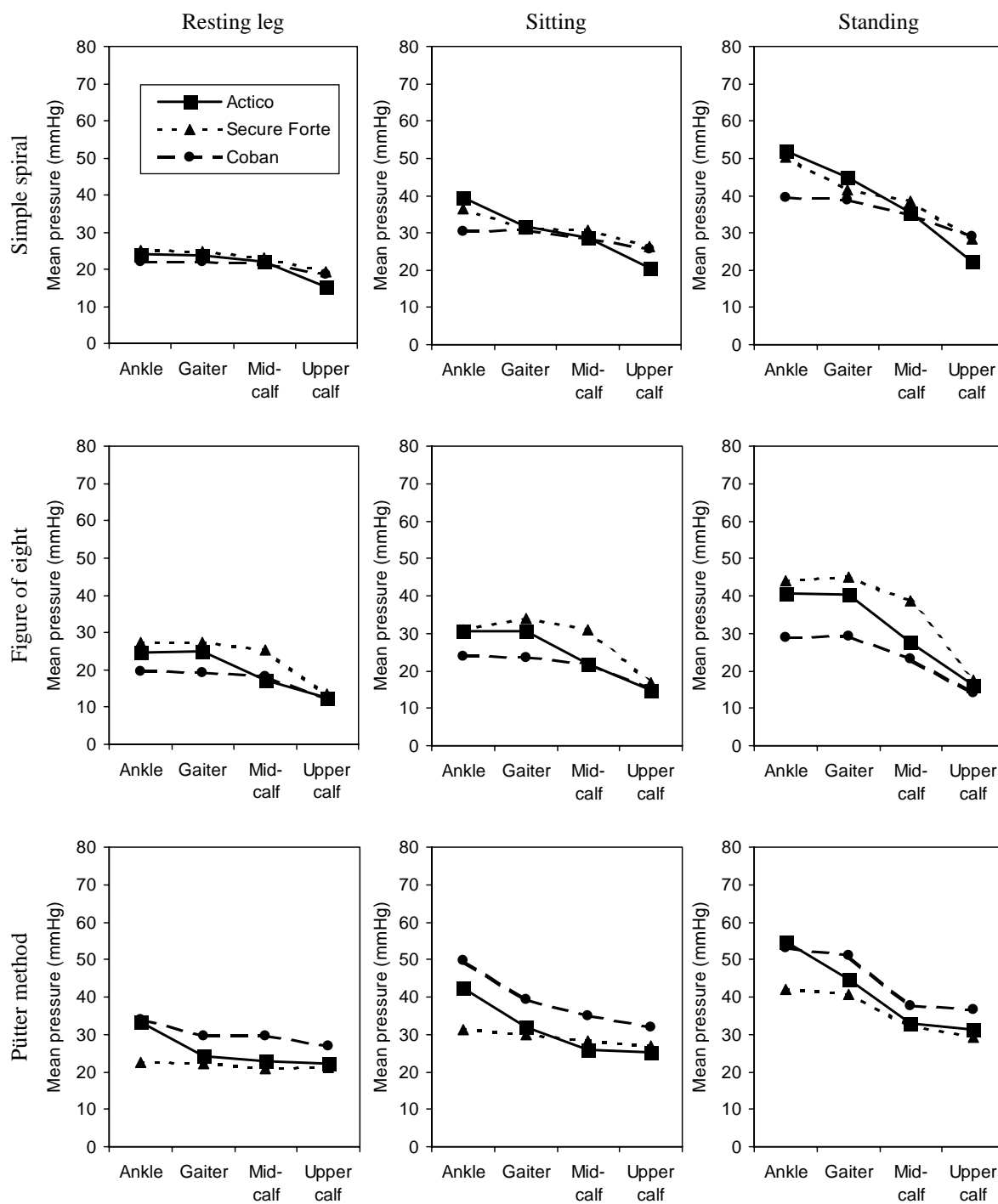


Fig. 6. Mean pressure over five blocks for each cohesive elastic bandage for different application techniques and postures.

For simple spiral, the pressures when measured on the resting leg were almost identical between cohesive E and non-cohesive NE bandages except that the pressures were slightly lower at the upper calf for the latter. On sitting, the pressure remained slightly lower at the upper calf for the non-cohesive NE

bandages, but was considerably higher at the ankle and slightly higher at the gaiter. This pattern of differences was more pronounced for standing. This resulted in a much larger gradient for non-cohesive NE bandages when applied in the simple spiral. For both the figure of eight and the Pütter method a similar

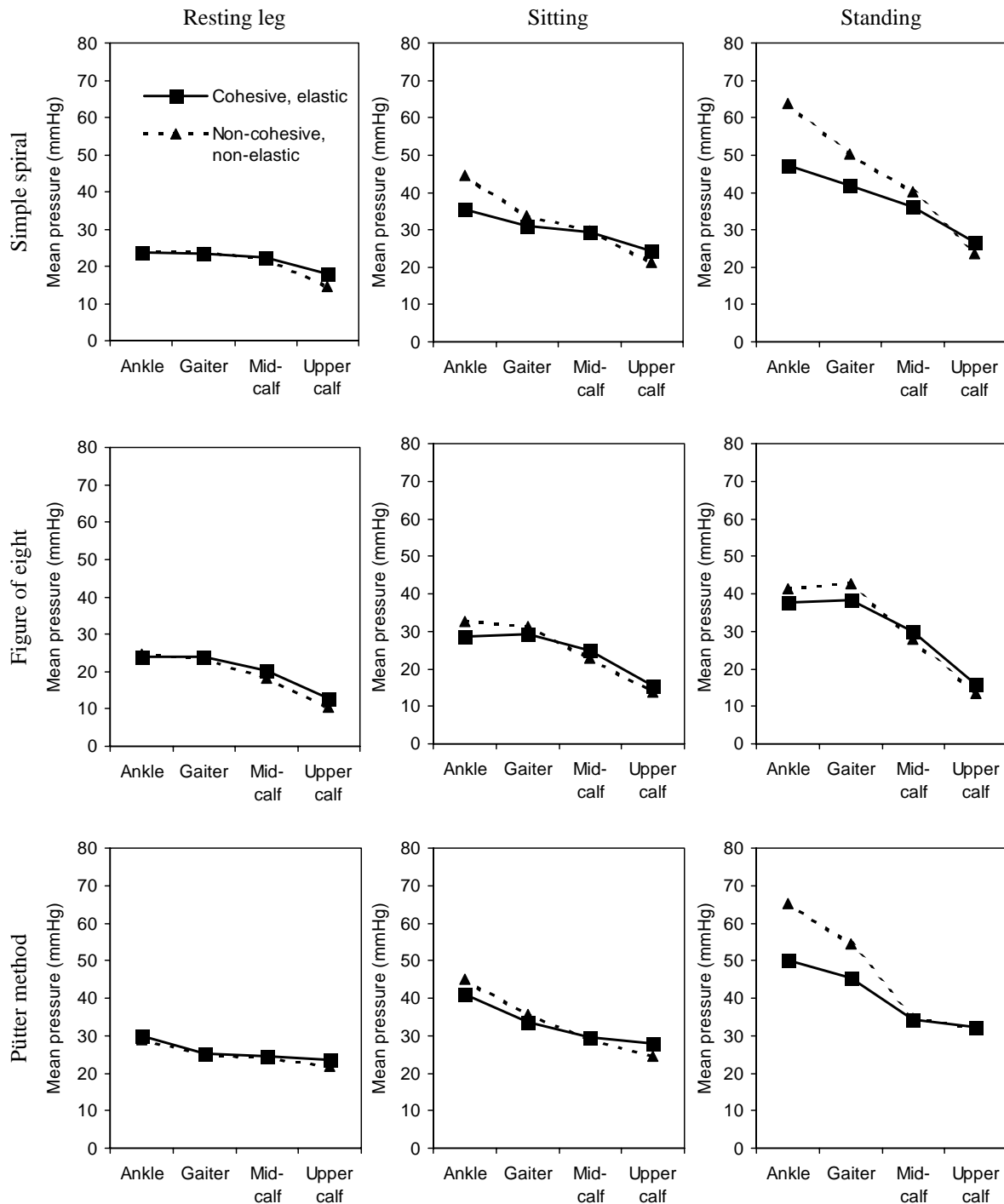


Fig. 7. Mean pressure for the two non-cohesive elastic bandages and the three cohesive non-elastic bandages for different application technique and postures.

pattern of differences occurred. However, for the Pütter method the differences were less marked for sitting, and for the figure of eight the magnitude of all the differences in pressures was small and probably not clinically relevant.

#### Reproducibility of pressures

The simple spiral and figure of eight application techniques had the same pooled SD (5.1) and the variability of the Pütter method was slightly higher



**Table 2. Which bandage and application technique is most consistent?**

Bandage type	Bandage	Application technique		
		Simple spiral	Figure of eight	Pütter method
Non-cohesive, NE	Actiban	5.66	4.60	6.70
	Comprilan	5.60	6.99	6.32
Non-cohesive, E	Tensopress	4.74	5.88	6.46
Cohesive, E	Actico	5.27	4.43	6.96
	Secure Forte	4.66	4.21	5.33
	Coban	4.69	4.09	6.63

Pooled standard deviation for each bandage and application technique combination.

(6.4). The pooled SDs were the same for each of the non-cohesive bandages (5.7), but the SDs for the cohesive bandages showed small differences: 6.3 (Actico), 5.2 (Coban) and 4.8 (Secure Forte). The pooled SDs varied for the bandages depended on which application technique was used, but in general the pooled SDs did not differ substantially for any combination of application technique or bandage (Table 2).

#### *Effects of changes in posture*

Figs. 5–7 show that the pressure is generally higher when standing compared to sitting and generally higher when sitting compared to resting regardless of bandage type or application technique. Simple spiral shows the largest percentage increase from resting to standing (mean 80%) compared to the Pütter method (62%) and the figure of eight (47%). The percentage increases in pressure on standing were inversely related to the stretch length of the bandage. The largest percentage increases occurred for the non-cohesive NE bandages (Actiban and Comprilan) (means 82–84%), followed by the shorter stretch cohesive bandages (Actico and Secure Forte) (64–65%), longer stretch cohesive bandage (Coban) (51%) and the high compression non-cohesive bandage (Tensopress) (34%). Overall, the effect is less noticeable

the higher up the leg the pressure is measured, with a mean increase of 87% occurring at the ankle falling to 79% at the gaiter, 51% at the mid-calf and 36% at the upper calf.

Table 3 summarises the findings. The largest percentage changes were seen with the simple spiral method. The results from the two non-cohesive NE bandages (Actiban and Comprilan) are very similar with average percentage increases at the measuring points of 121% at the ankle, 106% at the gaiter, 60% at the mid-calf and 45% at the upper calf. The two shorter stretch cohesive bandages (Actico and Secure Forte) were also similar to each other, but with rises that were less pronounced at the ankle and the gaiter (84, 77, 59 and 38%, respectively). The longer stretch cohesive bandage (Coban) and the high compression non-cohesive bandage (Tensopress) produced the smallest percentage changes with posture.

## Discussion

Bandages used to treat venous disease by compression should achieve and sustain effective levels and gradients of pressure and minimise the risk of pressure trauma. The particular bandages adopted for this study were chosen as they are widely marketed for leg ulcer care but without detailed information on performance.

It is difficult to draw conclusions from many published reports of compression therapy. Trials involving heterogeneous patient populations have included bandages of widely differing properties, used in a variety of combinations, with different techniques of application and bandagers. This study was designed to minimise the number of variables that could influence the findings, and to standardise the remaining variables. Bandages were applied by the same bandager to the same human volunteer at the same time of day. Each bandaging technique was carried out in a separate experiment to allow the

**Table 3. Percentage change in pressure (mmHg) from resting leg to standing**

Effect	Level	Mean (SE) for percentage change in pressure from resting leg to standing			
		Ankle	Gaiter	Mid-calf	Upper calf
Application technique	Simple spiral	122 (5)	87 (5)	65 (5)	49 (5)
	Figure of eight	56 (5)	64 (5)	45 (5)	25 (5)
	Pütter method	83 (5)	86 (5)	43 (5)	36 (5)
Bandage	Actiban	121 (7)	101 (7)	64 (7)	48 (7)
	Comprilan	121 (7)	111 (7)	55 (7)	42 (7)
	Actico	83 (7)	79 (7)	54 (7)	38 (7)
	Secure Forte	84 (7)	74 (7)	63 (7)	37 (7)
	Tensopress	51 (7)	40 (7)	29 (7)	17 (7)
	Coban	60 (7)	68 (7)	39 (7)	35 (7)

bandager to remain as consistent as possible. Without these precautions meaningful analysis would have been impossible. Despite the limited range of bandaged legs and bandagers we consider that similar results would have been obtained in a range of limbs by any competent bandager.

Despite the interactions between the variables in our experiments, a number of general points can be made. Importantly, the pressures on the resting leg were broadly similar for all bandages and within a therapeutically appropriate range. Differences became more apparent with changes of posture. Pressures were always lower at the upper calf than at the ankle, although the gradient was not progressive across the four measuring points in all cases. Irrespective of the bandage, the pressure gradient was steepest in the standing position and least in the resting posture for all techniques. The measurement technique allowed readings only to be taken when the subject was motionless and cannot reflect events during exercise. Hirai,<sup>7</sup> however, showed that pressure differences during activity reflect the application pressure. We found that non-elastic bandages achieved a greater pressure differences with changes in posture than elastic ones. The magnitude of the increases in pressure on standing was inversely related to the stretch length of the bandage. We did not find higher pressures on standing for the long-stretch (E) bandages reported by Danielson.<sup>8</sup>

Since, the Pütter method comprises three layers, it might be expected to achieve higher pressures than the single bandages. Surprisingly, our results showed that this was not the case. While all techniques produced acceptable resting pressures and gradients some of the pressures were exceptionally high when standing. The simple spiral and Pütter techniques, in spite of their major differences, gave remarkably similar pressures and gradient profiles. This may be due to the fact that in the simple spiral method the turns are much more horizontal than the Pütter technique. The figure of eight gave lower pressures generally and the gradient profile changes with posture were different from those of the other two techniques. Further research is needed to clarify the effects of combining the spiral and figure of eight techniques used in four layer systems.

Although the pressures generated by changes of posture were variable, for clinical purposes (as distinct from scientific laboratory measurement), all bandages and techniques gave relatively consistent pressures and gradients with all standard deviations (pooled over blocks) falling below 7 mmHg.

It is conventionally taught that compression therapy for chronic venous ulcer should deliver a

pressure of around 40 mmHg at the ankle and a diminishing ascending gradient. The evidence for this represents a compromise between pressures that have been shown to have effects on limb volume and blood flow<sup>9-17</sup> and pressures which the patient will tolerate. The therapeutic success of pressure in the gaiter region of around 40 mmHg is consistent with clinical experience.<sup>18</sup> The evidence favouring a gradient derives from very few scientific studies.<sup>19-21</sup> Authors seldom discuss the posture at which these pressures should apply. Our studies with short stretch non-cohesive bandages show that gaiter pressures were below 40 mmHg when measured on the horizontal resting leg, but rose to as much as 75 mmHg on standing with short stretch non-cohesive bandages—levels which would be considered dangerous, especially for patients with arterial insufficiency. In practice, these apparently dangerous levels would not be maintained because, during activity, the pressures in the extreme positions change rapidly as the conformation of the calf muscles changes with movement. Bandage pressure has been shown to decline by about 20% within a few hours of application<sup>22,23</sup> although cohesive and multi-layer bandages have been shown to sustain their pressures better.<sup>18,24-27</sup> Nevertheless, even if the pressure fell for some bandages, applied in a certain way the pressure would still be relatively high in the erect posture.

We recognise that effective compression should be sustained over time. This study was not designed to assess anything other than the pressures immediately after application. Longer term measurements would have greatly complicated this research but are required for a better understanding of this subject. Establishing the level of compression required for clinical efficacy will require detailed studies in patients with venous disease.

To avoid potential harm to a diseased leg,<sup>1</sup> it is important that the person who applies compression understands the physical properties of each bandage used and also the effects achieved with different bandaging techniques. There is no absolute pressure level, which is dangerous because in the arteriopath the danger depends on the difference between the arterial perfusion pressure and the compression pressure. In the diabetic limb the danger will vary according to whether neuropathy is present.

Our data indicate that bandagers should be particularly wary of non-elastic bandaging in patients who spend much time sitting or standing, especially if the Pütter or simple spiral methods are used. Theoretically, non-elastic bandages would have produced lower pressures than elastic bandages in the resting leg we did not find this. Further research is

necessary to determine the pressures achieved by different materials and different methods of application, their physiological and therapeutic effects over time and during activity.

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